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A Review of the Status of the Cod Stock in NAFO Division 3M

by

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Abstract

The analysis of the cod stock made last year indicated a collapse of the population, originally produced by a severe overfishing of some past abundant year-classes, that became heavier by the failure of the recruitment since 1995. New information from the fishery and from the July survey, both in 2000, coincides to indicate that the situation remains steady at a very low level without some sign that could foretell good recruitment.

Introduction

The stock is under moratoria since 1999, and its status had been qualified as collapse, attributed to three possible factors: a stock decline due to overfishing, an increase in catchability at low abundance levels and a very poor recruitment since 1995 (Vázquez *et al.* 1999). In last year analysis it was concluded that the stock total biomass and spawning biomass were at he lowest observed level, the recruitment of the last four years were the weakest observed and, in consequence, it was unlikely a recovery of the stock in a short o medium term (Cerviño and Vázquez 2000).

Since 1974, when a TAC was established for the first time, catches ranged from 48 000 tons in 1989 to a minimum of 55 tons estimated for 2000. Annual catches were about 30,000 tons in the last 80's, when the fishery was under moratoria, and they decline since then as a consequence of the stock collapse.

Assessment

Catches

There has not been directed fishery for cod in Flemish Cap in 2000. Reported catches are obtained as by-catch in other fisheries on the bank: only Portugal has reported catches of 2.9 tons in 1999 and 29.5 in 2000 as by-catch in the redfish fishery (Vargas *et al.* 2000, 2001). Spanish catches were estimated as 25 tons in 2000 based on Canadian Surveillance reports. Also based on Canadian Surveillance reports, catches of Non-Contracting Parties were estimated as 205 tons in 1998, 350 tons in 1999 and null in 2000. The cod by-catch in the shrimp fishery must be almost null due to the use of sorting grates.

Catch at age in numbers

Biological information on commercial cod catches was only available from the Portuguese fleet: two samples in April and July amounting 238 individuals, with mean length of 42 and 67 cm respectively. This sampling is considered poor taking into account that both samples were quite different and the mean length of the former sample has a mean length

well below the mean observed in the survey (mean is 61 cm when fish smaller than 30 cm, all age 1, are excluded). Length distribution were transformed to catch at age data (Table 1) using the age-length key from the EU survey in July 2000 (Saborido-Rey and Vázquez 2001), following the same criterion used for 1999 data, based on the similarity observed in previous years. Cod of age 2 had been caught, according to this procedure, as a result of numerous fish at the length range 39-41 cm. However, the two fish in this length range and attributed to age 2 in the age-length key were quite insecure: they are in the border of the expected length range. These age 2 fish were a source of problems in adjusting the XSA.

Mean weight-at-age in the catch was also calculated applying the weight-at-length relationship obtained in the survey to the observed length at age distribution.

Survey indices of abundance at age

Abundance indices at ages 1 to 7 for years 1988 to 2000 from the EU-survey are shown in Table 2. Abundances in this table are expressed in thousand fish instead of ten thousand because they became so low in the most recent years that otherwise some ages were not represented, producing a bad fit in XSA tuning.

Cod catches in the Faroese shrimp survey on Flemish Cap in June-July 1998 to 2000 were aged (Nicolajsen 2001). Those catches were made with a survey gear similar to the commercial one, but without sorting grade. Mean length at age data show good agreement with the EU survey results.

Maturity ogive.

Last maturity ogives calculated are from 1998 (Saborido-Rey and Junquera, 1999). Consequetly, the percentages maturity at age in 1999 and 2000 were assumed to be equal to those of 1998.

Natural mortality was assumed at 0.2.

Results

An XSA-Extended Survivor Analysis (Darby and Flatman 1994) was carried out with these inputs and the following settings:

Catch data for 29 years. 1972 to 2000. Ages 1 to 8+
Tuning with EU-survey for 1988 to 2000 and ages 1 to 7

Tapered **time weighting** was not applied.

Catchability analysis
Catchability dependent on stock size for ages younger than 3
Catchability independent of age for ages older than 4

Terminal population estimation
Terminal year survivor estimates shrunk towards last year F
Oldest age survivor shrunk towards F mean of ages 4-6
5.0 s.e. of the mean to which the estimates are shrunk
0.5 Minimum standard error for population estimates from each cohort

Some changes were introduced in these settings in relation to the last year analysis. Catchability was considered dependent on stock size for age 1 and 2 instead of age 1 because new data for age 2 give a bad catchability fit and the two parameters model improves the fit. Terminal population was shrunk towards last year F but the s.e. of this shrinkage was increased from 0.5 to 5.0.

Log catchability and its standard error are shown in Table 3, where high standard errors are mainly observed for ages 5 and 6. Results of the catchability analysis for the EU-survey are presented in Figure 1 and catchability residuals seem

to be reasonably consistent for ages 1 to 6 but not for age 7. Residuals of ages 6 and 7 are negative in 2000 and this could indicate an overestimation of their abundance.

Tables 4 and 5 show the XSA results of abundance and F at age since 1988. Mean fishing mortality at ages 3-5 declined since 1995 until 1999, and remain at that level in 2000. However, the fishing pattern in 2000 is completely different to the one observed for previous year. As no deep change has occurred in the commercial fleet, it must be concluded that this result is a consequence of using a very small sample of the catch, which is also biased to small fish.

Total abundance (Table 5) peaks in 1992 with 154 millions fish and has been decreasing since then until 1999, with less than 2 millions. Abundance in 2000 are 2.3 million fish, but the model attributes 1 million to age 1, which is a highly insecure estimate because it is based on only one year of survey results, so only 1.3 million fish should be for ages older than 1, and this implies a more pessimistic view that the one resulting from last year analysis. Recruitment at age one was scarce since 1993 and even poorest since 1996. This period with poor recruitments produced a population at the beginning of 2001 (Table 5) where fish younger than 6-years old are scarce, excluding age 1 already commented; age 7 is the more abundant class and represents a half of the population abundance. The abundance attributed to age 1 in the analysis is higher than that attributed to the previous four years, but it is well below of levels observed in the 1993 to 1995, also considered as poor recruitments. Those results are also consistent with survey results, where catches at age 1 were higher than in the previous four years.

Biomass, spawning stock biomass, recruitment at age 1 and mean F at ages 3 to 5 were calculated from XSA results and are presented in Table 6. Recruitment at age one present three peaks (Figure 2), 1974, 1986 and 1991-92, consequently total biomass presents also three peaks in 1976, 1989 and 1992, the latest being the less important. The relative high abundance of those year-classes is also observed in the SSB they produced years later, those peaks of 1979 and 1990-92, but no later that should be corresponded to the latest recruitment peak of 1991-92. This could be a consequence of the overfishing at that time; in 1989-90 catch peaks coinciding with high biomass (Figure 3); the biomass decreased in following years but F increased in 1992-95, overfishing the year-classes that produced the last recruitment peak. After 1995 biomass decreased to a level around 3 thousand tons.

In last year analysis (Cerviño and Vázquez 2000) total biomass showed an increasing trend after the low in 1996, but a possible overestimation of the population and SSB in last years was envisaged. Total biomass, according to the current analysis, has basically the same values up to 1995, but total biomasses for 1996 onwards are lower and have a decreasing trend. Current analysis indicates a minimum of both total biomass and SSB in 1999, and a slight increase to 2000 due to the growth in weight of the fish under a low fishing mortality regime.

The stock-recruitment relationship using both SSB and recruitment at age one from XSA results is presented in Figure 4. Recruitment and SSB since 1992 are the lowest in the series. The plots show the same two different zones, already pointed in last year analysis, where the probability of getting good recruitments is different. This was the base to estimate a preliminary figure for B_{lim} as 14 000 tons; the average recruitments is 14 millions fish when SSB was below 14 000 tons and it was 48 millions when SSB was above this amount.

Results of a retrospective analysis are presented in Figure 5. Fishing mortality was underestimated in last years and, consequently, total biomass and the spawning stock biomass were overestimated.

The role of the future recruitment level in the rebuilding of the stock was analysed by simulation. The surviving population at the beginning of 2001, his numbers at age according to XSA results, were projected to 5 and 10 years later, assuming a constant recruitment. Fishing mortality was also considered constant during the period. Results of this exercise are presented in Figure 6, where the 14 000 tons of SSB (B_{lim}) are indicated. This level is never achieved if recruitment is 1 million fish, even with no fishing mortality. However, the current level of recruitment is equal or below this value since 1996 according to XSA results (Table 5). The target SSB is not achieved in a five years period at a recruitment level of 5 million fish and no fishing. This recruitment level was not observed since 1992.

Discussion

The total biomass indices from the EU survey and XSA results show the same view in most recent years. Both indices decline up to 1999 and have a slight increase for 2000. Also recruitment at age one in VPA shows a similar pattern as the EU survey along the analysed period. Discrepancies were also observed in last year analysis on abundance of

recruited year-classes, but the agreement in the current analysis is good: both sources indicate age 3 the most abundant year-class in 2000 among the youngest cohorts, and age 6 the most abundant among the oldest ones.

The main conclusion of the analysis, already pointed in previous years, is that both total biomass and SSB are at the lowest observed level, and recruitment remain among the weakest observed. The SSB at the low current levels was not able to produce good recruitments in recent years. With the present age structure of the population it is unlikely a recovery of the stock in a short or medium term.

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Table 1 – Catch in numbers (‘000).

	age							
year	1	2	3	4	5	6	7	8+
1972	0	0	278	19303	12372	6555	3083	3177
1973	0	0	2035	116	11709	3470	853	1085
1974	0	0	5999	11130	2232	1894	271	257
1975	0	0	7090	2436	1241	238	281	258
1976	0	0	17564	10653	386	100	63	5
1977	0	0	119	17581	8502	436	267	318
1978	0	0	428	3092	18077	3615	329	270
1979	0	0	167	2616	5599	5882	316	137
1980	0	0	551	500	1423	1051	1318	96
1981	0	0	1732	6768	161	326	189	539
1982	0	0	21	3040	1926	310	97	357
1983	0	0	2818	713	765	657	94	131
1984	0	0	9	2229	966	59	90	146
1985	0	0	19	5499	3549	1232	931	218
1986	0	2549	2266	4251	2943	1061	169	162
1987	814	1848	3102	1915	1259	846	313	112
1988	1	3500	25593	11161	1399	414	315	162
1989	0	52	15399	23233	9373	943	220	205
1990	7	254	2180	15740	10824	2286	378	117
1991	1	561	5196	1960	3151	1688	368	76
1992	0	15517	10180	4865	3399	2483	1106	472
1993	0	2657	14530	3547	931	284	426	213
1994	0	1219	25400	8273	386	185	14	182
1995	0	0	264	6553	2750	651	135	232
1996	0	81	714	311	1072	88	0	0
1997	0	0	810	762	143	286	48	0
1998	0	0	8	170	286	30	19	2
1999	0	0	15	15	96	60	3	1
2000	0	0	54	1	1	4	1	0

Table 2 – Indices of abundance at age from the EU survey (‘000) and biomass in tons by swept area method.

	Age								
Year	1	2	3	4	5	6	7	8+	biomass
1988	4576	72615	40564	10665	1230	191	223	110	37127
1989	20803	11028	84280	49151	18573	1270	157	80	103644
1990	2492	11937	4755	15469	14660	4298	350	240	55360
1991	137814	25600	15381	1928	6283	1674	296	60	36597
1992	71190	37060	4748	2033	332	1255	222	20	24295
1993	4364	132237	28403	1010	1269	168	491	100	55642
1994	3147	3835	24599	4562	120	66	7	130	24062
1995	1546	11365	1238	3595	885	33	25	20	8815
1996	39	2964	6131	820	2247	187	8	10	8196
1997	39	139	3146	4360	358	902	20	10	9063
1998	25	76	85	1137	1449	73	144	10	4532
1999	6	78	102	105	655	415	19	10	2596
2000	175	13	276	173	84	407	163	50	2782

Table 3 - Log catchability and standard error from XSA output.

Age	3	4	5	6	7
Mean Log q	0.1899	0.0298	0.1581	0.1581	0.1581
S.E(Log q)	0.5760	0.6867	0.9568	0.7823	0.2159

Regression statistics :

Ages with q dependent on year class strength

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Log q
1	0.75	3.053	2.77	0.93	13	0.66	-0.99
2	0.83	2.556	1.38	0.96	13	0.55	-0.01

Ages with q independent of year class strength and constant w.r.t. time.

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Q
3	1.01	-0.097	-0.25	0.94	13	0.61	0.19
4	1.15	-1.354	-1.26	0.88	13	0.76	0.03
5	1.01	-0.058	-0.24	0.72	13	1.01	0.16
6	1.1	-0.458	-0.76	0.67	13	0.89	0.12
7	1	-0.046	-0.07	0.99	13	0.2	0.06

Table 4 - Fishing mortalility from VPA.

age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	0.0001	0	0.0003	0	0	0	0	0	0	0	0	0	0
2	0.0612	0.0042	0.0157	0.0278	0.3631	0.0589	0.7128	0	0.0302	0	0	0	0.1556
3	0.4120	0.4145	0.2404	0.5016	0.9807	0.6944	1.2312	0.3216	0.2997	0.4683	0.0625	0.118	0.3916
4	0.5332	0.8330	1.0253	0.3545	1.3658	1.2348	1.1946	1.4449	0.7893	0.6080	0.1662	0.1599	0.0103
5	0.5366	1.2822	1.3465	0.5748	2.3156	1.1463	0.3916	2.7286	1.0431	1.1238	0.4839	0.1332	0.0142
6	0.7982	0.8787	1.4957	0.7802	1.3767	2.6854	0.7361	4.3712	0.8195	0.9136	0.7595	0.1737	0.0073
7	1.3569	1.5746	1.1687	1.1418	2.9165	0.9693	1.7298	3.4898	0	1.8685	0.1292	0.1495	0.0039
8+	1.3569	1.5746	1.1687	1.1418	2.9165	0.9693	1.7298	3.4898	0	1.8685	0.1292	0.1495	0.0039
F 3-5	0.4939	0.8433	0.8707	0.4770	1.5540	1.0252	0.9391	1.4983	0.7107	0.7334	0.2375	0.1370	0.1387

Table 5 - Abundance at age (‘000) from VPA.

age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	16888	22063	27622	68799	62731	3228	4545	3681	218	222	275	94	1011	
2	65120	13826	18064	22609	56327	51360	2643	3721	3014	178	182	225	77	830
3	83767	50149	11273	14560	18003	32076	39646	1061	3047	2394	146	149	184	54
4	29845	45425	27125	7257	7219	5528	13115	9477	630	1848	1227	112	108	102
5	3723	14336	16169	7966	4168	1508	1317	3252	1829	234	824	851	78	88
6	832	1782	3256	3444	3671	337	392	729	174	528	62	416	610	63
7	469	307	606	597	1292	759	19	154	8	63	173	24	286	496
8+	236	278	184	121	528	373	238	252	0	0	18	8	0	233
total	200879	148166	104298	125352	153939	95169	61914	22325	8918	5467	2907	1878	2355	1867

Table 6 - Recruitments at age 1 (‘000), total biomass, spawning stock biomass (SSB), landings (tons), mean F at ages 3-5 and biomass index from EU-survey.

year	recruits (age 1)	Total biomass	SSB	landings	Yield/SSB	F 3-5
1972	18861	83839	40474	57503	1.421	0.689
1973	66655	46551	21415	22900	1.069	0.569
1974	134636	37829	14414	24938	1.730	1.289
1975	24746	49619	8240	22375	2.716	0.606
1976	11147	113363	9973	22266	2.233	0.334
1977	3579	87518	22761	27019	1.187	0.465
1978	22791	56861	28585	33131	1.159	0.453
1979	16217	46618	32500	29710	0.914	0.725
1980	8548	32000	14785	10468	0.708	0.511
1981	23238	32182	9460	13873	1.466	0.453
1982	22425	30643	11920	12753	1.070	0.490
1983	13950	42836	13149	10215	0.777	0.236
1984	15879	39521	16829	12702	0.755	0.229
1985	62936	37401	19203	13675	0.712	0.550
1986	127460	35667	12648	14518	1.148	0.747
1987	80437	54699	11253	10632	0.945	0.445
1988	16888	67940	11001	28899	2.627	0.494
1989	22063	109271	19135	48373	2.528	0.843
1990	27622	66630	23544	40827	1.734	0.871
1991	68799	46159	18863	16229	0.860	0.477
1992	62731	60341	20718	25089	1.211	1.554
1993	3228	48268	10516	15958	1.518	1.025
1994	4545	47831	18524	29916	1.615	0.939
1995	3681	21951	18591	10372	0.558	1.498
1996	218	5736	3190	2601	0.816	0.711
1997	222	4992	2940	2933	0.998	0.733
1998	275	3819	3443	705	0.205	0.238
1999	94	3083	2860	353	0.123	0.137
2000	1011	3370	3056	55	0.018	0.139

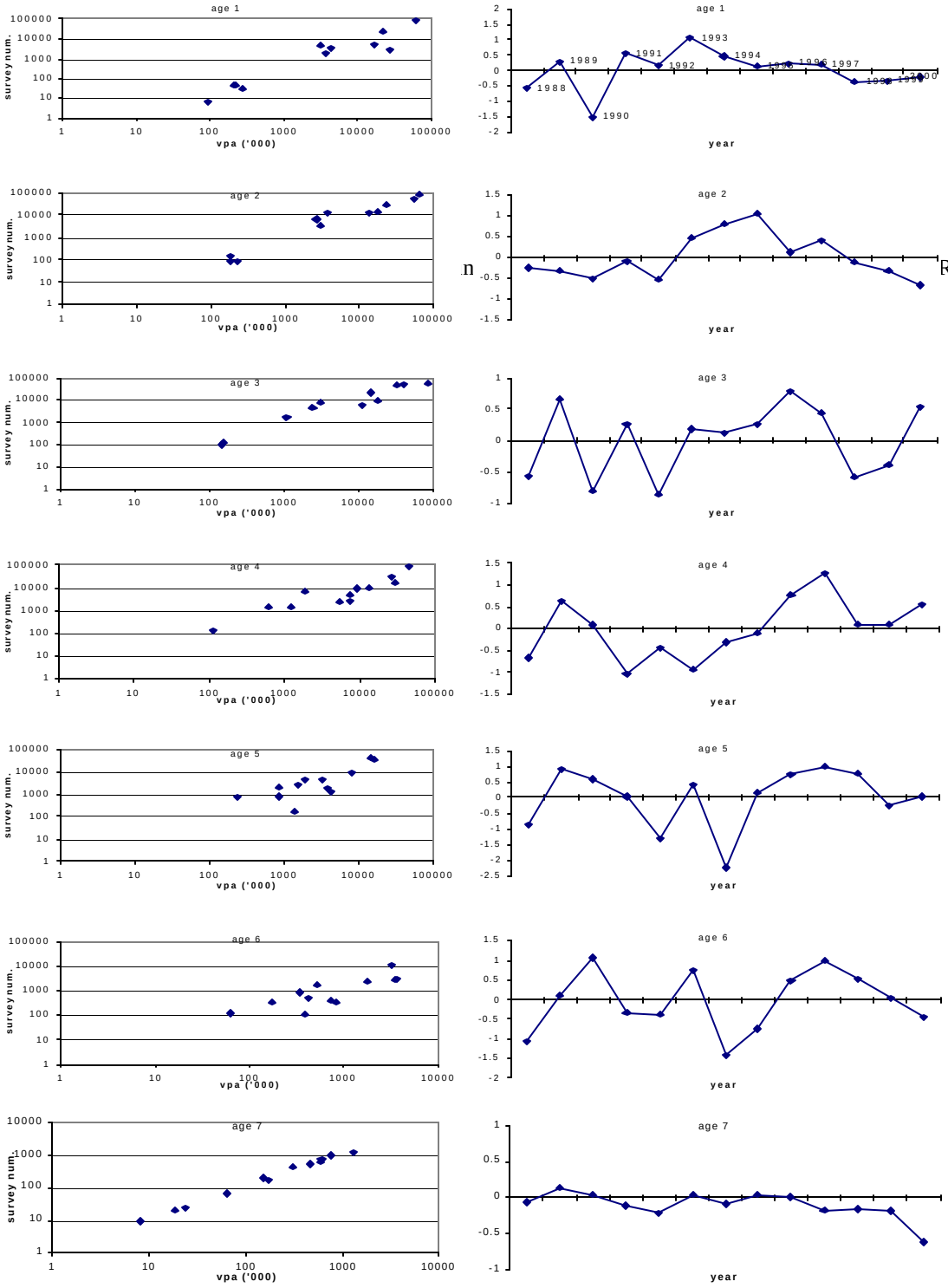

Figure n Right:

Figure 1 - Plots of catchability analysis by age. Left: abundance index from EU-survey against VPA results. Right: catchability residuals.

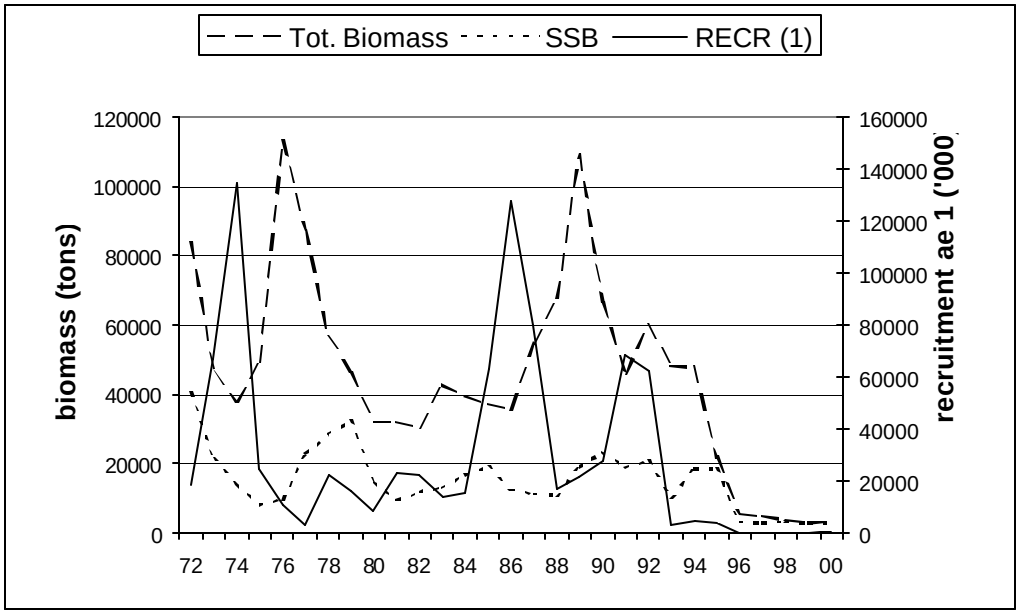

Figure 2 - Total biomass, spawning stock biomass and abundance of recruitment at age 1 according to XSA results.

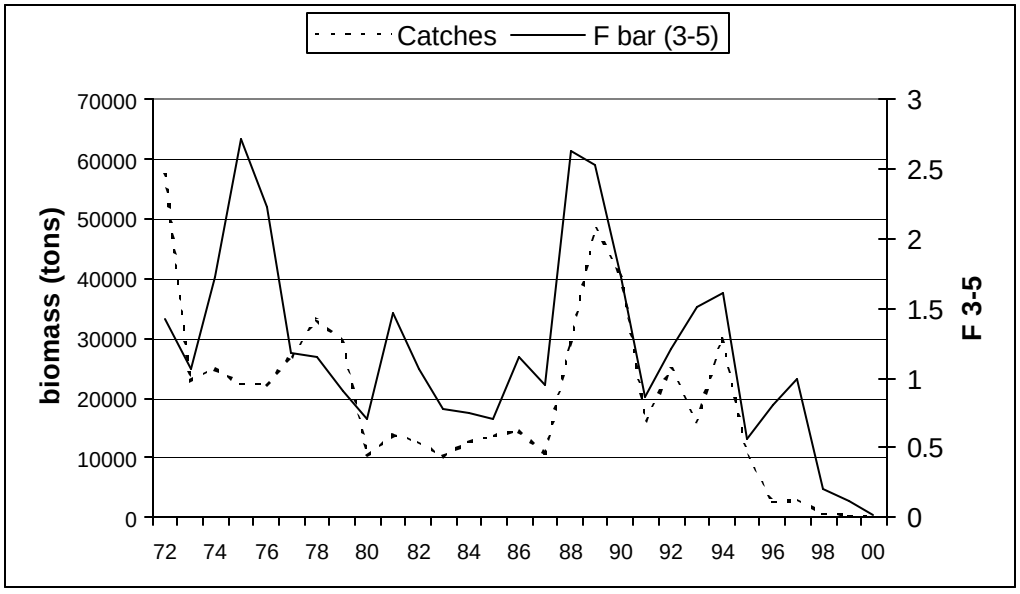

Figure 3 - Total annual catch and fishing mortality (F 3-5) according to XSA results

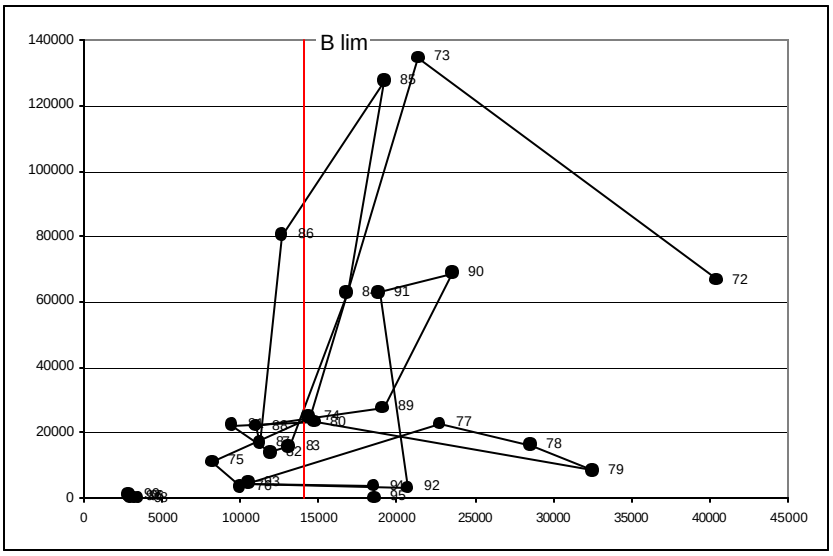

Figure 4 - Spawning stock biomass (SSB) and recruitment at age 1 from 1972 to 2000. Tag shows the year of SSB.

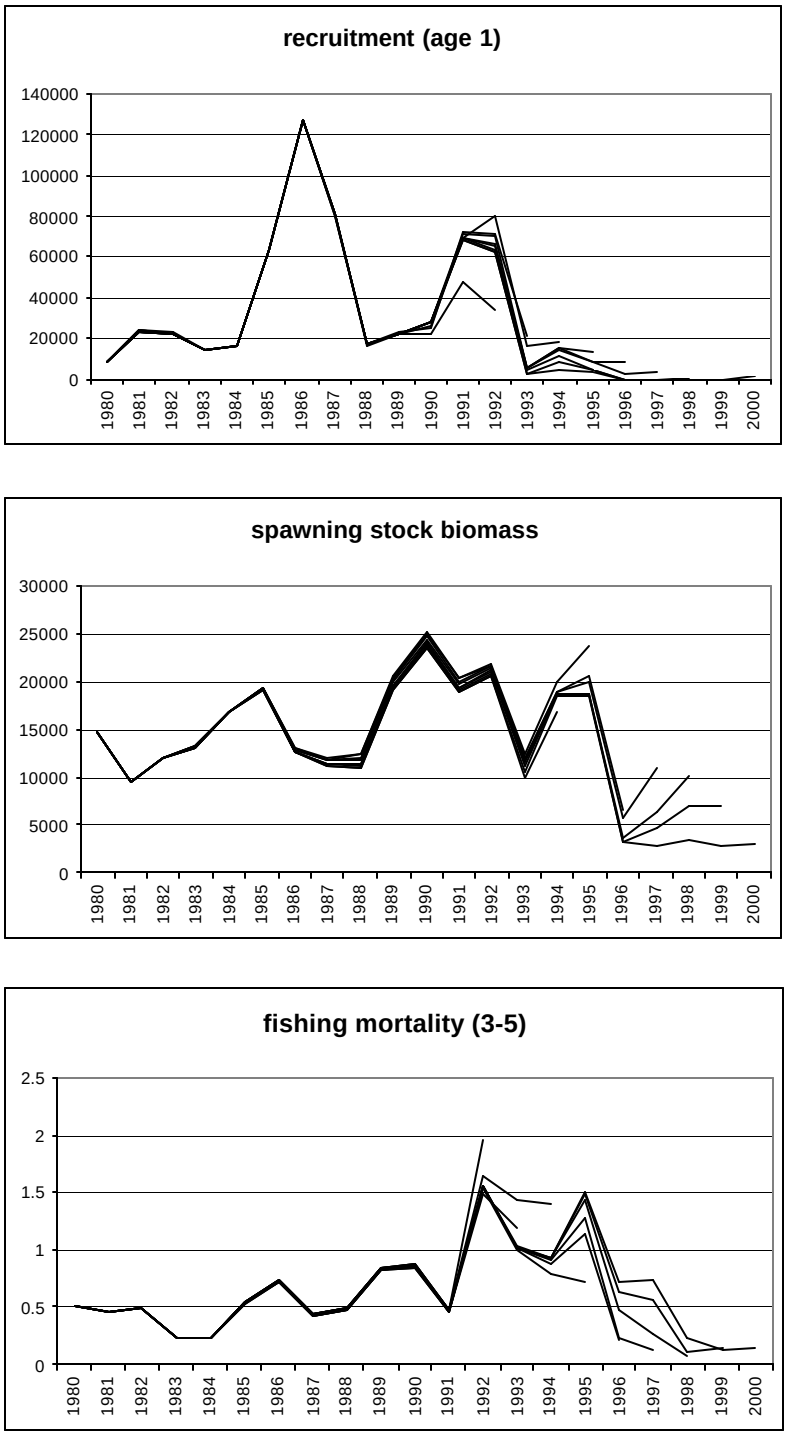

Figure 5 – Retrospective analysis for recruitment at age 1, SSB and F 3-5.

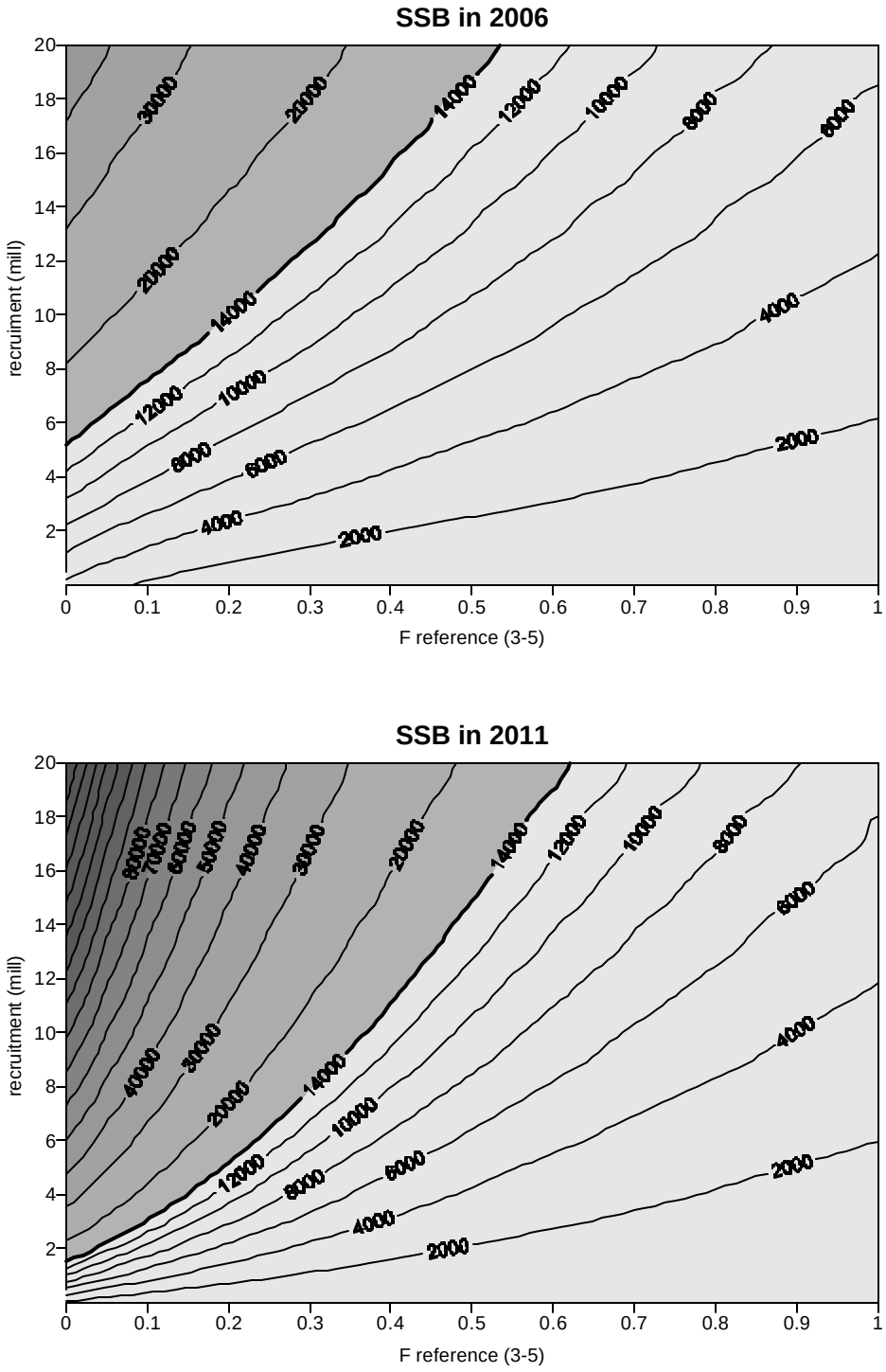

Figure 6 – SSB projections with different values for recruitment and F.